

A stiff south wind was blowing directly on the telescope and making measures impossible, but the definition was superb. During moments of steadiness the view was a sublime one, and impressed me more with the wonderful power of our great telescope than anything else, perhaps, that I have seen through it.

No abnormal features, however, were visible, either upon the rings or on the ball.

The narrow dark belt near the equator, shown in my drawing for 1894, was very distinct, but the space between it and the north dusky region seemed narrower.

This region north of it is really now a very broad warmish dusky belt distinctly terminated at its north edge, which lies about halfway from the trace of the crape ring to the north pole. From the north edge of this belt the surface of the ball was of an exceedingly delicate light yellow, apple-green colour. But at the pole there was a small, very heavily marked dark cap, which was nearly as dark as the crape ring against the sky. This small dark cap was strikingly and sharply defined in outline. I had seen this previously this year, and also last year, but not near so distinctly.

The Encke "division" was seen faintly at both ansæ, but more distinctly following. It was nearly as broad as the Cassini division.

The shadow of the ring on the ball was not visible, but the shadow of the ball on the ring was noticeable preceding the ball. It was narrow, slightly concave, and concentric with the ball. At the following side there was a darkening of the ring and the ball suggestive of the faintest trace of the shadow on that side.

The trace of the crape ring was pale and the ball was easily seen through it up to the bright ring. On the sky it was clearly defined, very distinct, and of a steely blue colour.

1895 April 1.

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*Filar Micrometer Measures of the Diameters of the Four Bright Satellites of Jupiter, made with the 36-inch Equatorial of the Lick Observatory.* By E. E. Barnard, A.M., Dr. Science.

The great power and large scale of the 36-inch make it very suitable for measuring very small quantities, such, for instance, as the diameters of the larger asteroids, the satellites of *Jupiter*, and so on.

In connection with my other work on the planet *Jupiter*, I began a series of micrometer measures of the diameters of the four bright satellites with the 36-inch.

These have been continued until the bad weather put a stop to the work. It is scarcely probable that any more satisfactory measures of these satellites will be obtained this winter; I have, therefore, collected and reduced the observations as final.

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A power of 1,000 has been uniformly used, and unless the night would permit the use of this magnifying power, and give distinctly defined discs, no measures were attempted.

The measures in each case were made by the method of double distances, three to four settings, before and after reversal of the wires, being made.

The endeavour in these observations has been to exactly bisect the limbs of the satellites with the centres of the wires. This, I think, can be done with an extremely small percentage of error. I should think this method more accurate than that of bringing the insides or the outsides of the wires tangent to the limbs, and then correcting for the thickness of the wires. If the images were absolutely steady and permitted one to deliberately bring the edges of the wires in exact tangency, then that method would be preferred. This condition of things, however, essentially never occurs. The thickness of the micrometer wires in the 36-inch micrometer is about  $0''.1$ .

Following are the details of the measures.

The full aperture of the 36-inch, as always, has been used.

*Satellite I.*

	Apparent Diam.	At $\Delta$ 5.20.	Deviation from Mean.
<sup>1894.</sup> Oct. 21	1".08	0".97	+0".08
28	1".02	1".12	-0".07
29	1".13	0".99	+0".08
Nov. 4	1".19	1".07	-0".02
5	1".33	1".14	-0".09
12	1".27	1".07	-0".02
18	1".24	1".03	+0".02
19	1".19	0".99	+0".06
Mean ... ..	...	1".048	

The measured diameters of this satellite are all *equatorial*, except on the following dates, November 4, 5, 18, when the *polar* diameter was measured.

*Satellite II.*

	Apparent Diam.	At $\Delta$ 5.20.	Deviation from Mean.
<sup>1894.</sup> Oct. 21	0".82	0".73	+0".14
28	0".93	0".81	+0".06
29	0".96	0".84	+0".03
Nov. 4	1".05	0".90	-0".03
5	1".21	1".04	-0".17
12	1".10	0".93	-0".06
18	1".03	0".85	+0".02
19	1".08	0".89	-0".02
Mean ... ..	...	0".874	

All the measures of this satellite are *polar*.

Satellite III.

	Apparent Diam.	At $\Delta$ 5.20.	Deviation from Mean.
<sup>1894.</sup> Oct. 21	1".85	1".66	-0".14
28	1.60	1.40	+0.12
29	1.66	1.45	+0.07
Nov. 4	1.77 (Equ.)	1.50	+0.02
4	1.73 (Pol.)	1.46	+0.06
5	2.03	1.74	-0.22
11	1.86	1.57	-0.05
12	1.77	1.49	+0.03
18	1.79	1.49	+0.03
19	1.86	1.54	-0.02
Dec. 23	1.79	1.43	+0.09
Mean ... ..	...	1.521	

Two measures of this satellite were made on November 4—equatorial and polar. The slight difference doubtless means nothing. All the other measures are *polar*.

Satellite IV.

	Apparent Diam.	At $\Delta$ 5.20.	Deviation from Mean.
<sup>1894.</sup> Oct. 21	1".58	1".41	+0".02
28	1.58	1.38	+0.05
29	1.58	1.38	+0.05
Nov. 4	1.62	1.39	+0.04
5	1.85	1.58	-0.15
11	1.73	1.46	-0.0
12	1.69	1.42	+0.01
18	1.66	1.38	+0.05
19	1.77	1.47	-0.04
Mean ... ..	...	1.430	

All the measures are *polar*.

Results.

We have therefore for the dimensions of these four satellites from the measures with the 36-inch, at distance 5.20—

Satellite	I.	1".048	$\pm 0".016$	(8 nights)
"	II.	0.874	$\pm 0.022$	(8 nights)
"	III.	1.521	$\pm 0.023$	(10 nights)
"	IV.	1.430	$\pm 0.015$	(9 nights)

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These correspond to the following values :—

Diameter	I.	2452	± 37 miles
	„ II.	2045	± 51 „
	„ III.	3558	± 54 „
	„ IV.	3345	± 35 „

*Early Estimations and Measures of the Diameters of the Satellites.*

Numerous early attempts were made to determine the dimensions of these four satellites before telescopes were powerful enough to make proper direct measures of their diameters. A collection of these early efforts is found in the *Vade Mecum* of Houzeau. I shall call on that valuable book for most of the information that follows.

The methods generally employed in these determinations depended upon the known motions of the satellites in connection with the phenomena of eclipse transit occultation, &c.

I shall indicate the method employed by the following initials :—

Entrance into eclipse (E) (this method ought to give too small a value).

Entrance in transit (T).

Entrance in occultation (O).

Measures of the satellite's shadow (S).

This last method I suppose was resorted to because the shadows would be better defined than the satellites' discs.

1693—*Cassini* (E).

I.	II.	III.	IV.
1''·92	1'·97	2'·06	1''·96

This result makes the satellites all essentially of the same dimension, yet his telescope must have shown him that there was really a considerable difference in size.

1734—*Maraldi* (T).

I.	II.	III.	IV.
2''·0	2''·0	2''·2	2''·0

1738—*Whiston* (E).

I.	II.	III.	IV.
1''·98	1''·47	1''·95	1''·64

1771—*Baily* (E).

I.	II.	III.	IV.
1''·9	1'·54	1''·85	...

1788—*Lalande* (E).

I.	II.	III.	IV.
...	...	...	1' 40

1797—*William Herschel* (T and S).

I.	II.	III.	IV.
...	0'' 9 (T)	1'' 6 (S)	...

1798—*Lalande* (O and T).

I.	II.	III.	IV.
...	...	...	1'' 4

1798—*Schroeter* (T).

I.	II.	III.	IV.
1'' 16	0'' 95	1'' 75	1'' 18

By combining his measures with those of Harding

I.	II.	III.	IV.
1'' 063	0'' 870	1'' 543	1'' 074

by direct measures he got

I.	II.	III.	IV.
1'' 15	0'' 80	1'' 87	1'' 17

by measures of the shadows of the satellites on the planet (S)

I.	II.	III.	IV.
...	0'' 83	1'' 488	1'' 273

I have taken the means of these various attempts of this astronomer. They are—

I.	II.	III.	IV.
1'' 124	0'' 862	1'' 663	1'' 174

These results of *Schroeter* are by far the most successful of the early attempts. They are accordant throughout, and differ in minute quantities only from the best determinations made with the most powerful telescopes of to-day. It is certainly a remarkable and highly creditable work for the industrious and accurate astronomer of *Lilienthal*.

*Later Measures of the Diameters.*

From this time on the measures were made with telescopes sufficiently powerful to give reliable results, and I shall collect them in tabular form, and have added my own to them.

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*Filar Micrometer and other Measures of the Diameters of Jupiter's Satellites.*  
By Different Observers.

Date.	Observer.	I.	II.	III.	IV.
1829	F. Struve	1"015	0"911	1"488	1"273
1856	Secchi	0"985	1"054	1"609	1"496
1863	Mädler	1"200	1"132	1"519	1"300
1871	Engelmann	1"081	0"910	1"537	1"282
1880	Hough	1"114	0"980	1"778	1"457
1891	Burnham	1"112	1"002	1"783	1"609
1894	Barnard	1"048	0"874	1"521	1"430

*Photometric.*

1879	Pickering	0"924	0"865	1"096	0"651
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*Interference.*

1891	Michelson	1"02	0"94	1"37	1"31
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Engelmann's results are a combination of micrometer measures and observations of the duration of passing the limb of *Jupiter* at transit.

Mr. Burnham's measures were made (with the 36-inch) on one night only, for Professor Michelson, in 1891.

The measures of Michelson were made in 1891, by his method of interference, with the 12-inch equatorial of the Lick Observatory.

Taking the means of these nine sets of measures by nine different observers, omitting Pickering's result for Satellite IV., we have for the diameters of

I.	II.	III.	IV.
1"055	0"963	1"522	1"395

with which my observations are in good accordance, and from which they differ by

I.	II.	III.	IV.
+ 0"007	+ 0"089	+ 0"001	- 0"035

These measures, made by the same observer with the same instrument and magnifying power, ought to lead to entire confidence in the results of my measures of the diameters of the minor planets, *Ceres*, *Pallas*, and *Vesta* (see *M.N.*, Vol. LIV. No. 9).

*The White Equatorial Belt on the First Satellite.*

The existence of the white equatorial belt and dark poles of Satellite I. has been amply verified at every favourable opportunity. They are beyond question permanent features of the

satellite, and will always be visible when a favourable transit occurs. At present the transits of I. are projected on the dark reddish south equatorial belt. This condition brings the white belt on the satellite into striking prominence, at the same time that it makes it rather hard to see the dark polar caps. But when the air is steady, with the 36-inch the entire satellite can be seen projected on the dark background. The phenomenon is then very beautiful. The white belt appears like a thin strip  $0''.1$  or  $0''.2$  broad, and the polar regions are very dark—almost black. Without close attention the satellite then simply looks like a thin white strip  $1''$  long by  $0''.1$  or  $0''.2$  broad. But careful inspection, with sufficient power, will show the entire satellite—white belt, dark poles and all. The belt is then seen to cut distinctly across the middle of the satellite.

In all the late observations of this satellite the belt seems to be exactly parallel to the belts of *Jupiter*, though at some of the former observations it has appeared inclined a couple of degrees from the Jovian equator.

I have previously called attention to the phenomena of the transits of this moon. When it first enters in transit, it is seen as a small round white spot, sharply contrasted with the dusky edge of *Jupiter*. As it enters further and the contrast is less, it becomes slightly elliptical in the direction of *Jupiter's* equator. As it progresses further, this ellipticity becomes rapidly greater. Presently a moment comes when the dark poles equal the brightness of the background, and they disappear; the white belt is then alone visible, and the satellite appears as a thin white strip. If the transit should carry it across a bright part of *Jupiter's* surface, the phenomenon of duplicity appears. The white belt is lost in the brightness of the background, and the dark poles appear as two dark spots—entirely separate—making the satellite appear double in a line perpendicular to the equator of *Jupiter*. If, however, in transit, it should be projected on a dark part of the planet, the dark poles in general will be lost in the background, and the satellite will appear very much elongated parallel to *Jupiter's* equator, the white belt alone being seen.

I have looked carefully for any elongation of this satellite when on the sky. Several times I have thought it elongated towards *Jupiter*, but a careful inspection has never convinced me that the elongation was real. With not the best seeing, this appearance of elongation was more decided. Where a casual inspection would seem to show elongation—or polar flattening—a closer inspection would dispel the appearance.

In speaking of his observations of the form of the disc of this satellite with the 36-inch, in a paper dated 1894 June 9 in *Astronomical Journal*, No. 321, vol. xiv., Professor Schaeberle says that to him the disc of I. “appears round only when it is very near to or projected on the disc of *Jupiter*, and elongated in the direction of the planet's equator in all other positions.”

If this were due to a true polar flattening it would suggest a

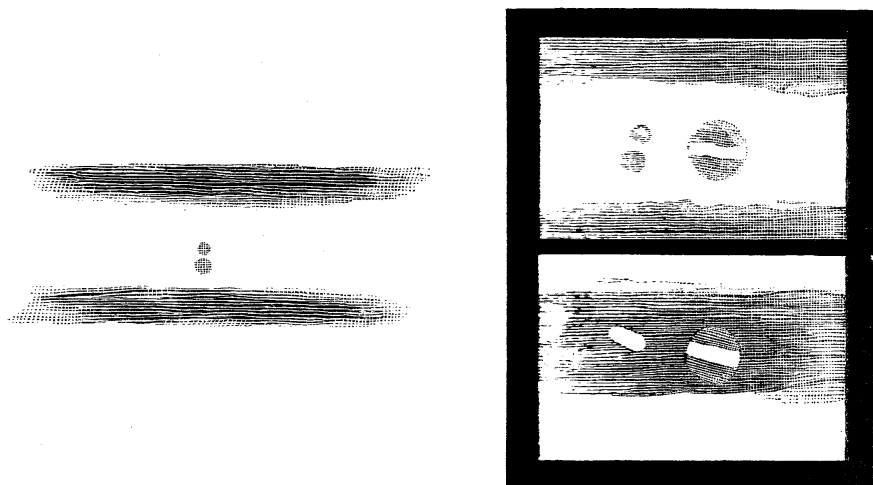


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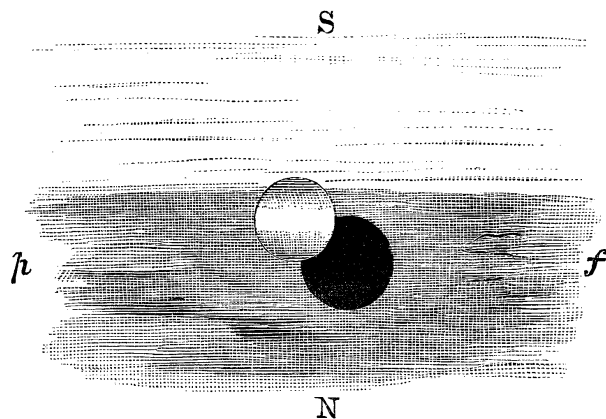
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very rapid rotation of this satellite and not one coincident with its period of revolution. For thus to be seen elongated in essentially all parts of its orbit it must be more or less lens-shaped and not egg-shaped, with the smaller end towards *Jupiter*, or it could not be seen elongated in all parts of its orbit.



Double transit of Satellite I.,  
1890 September 8.

Satellite I., 1890 September 8 and 1891  
August 3. and explanation of the  
phenomena.



Transit of Satellite I. and its shadow, 1893 November 19; showing the  
phenomena of bright equatorial belt and dark poles.

Professor Schaeberle has also seen it elongated in transit, for we both watched it one night this winter with the 36-inch, when it appeared as a thin white strip about one second long and about two-tenths second broad projected on the south reddish equatorial belt and parallel with *Jupiter's* equator. At that time, during moments of best seeing, the entire satellite was visible, the poles were very dark—almost black.



I think there is no sort of question but this appearance of elongation on the sky is simply a natural result of the bright equatorial belt and dark polar caps. The satellite actually does become conspicuously elongated when in transit, but no one then watching it would attribute the appearance to a real polar flattening. Now, on the sky this must have a more or less similar effect, through the darkness of the poles and the brightness of its equator. A lack of contrast with the sky in one direction and a good deal of contrast in another, aided by irradiation, and the satellite might well appear elongated towards the planet. This appearance of elongation would doubtless be augmented by indifferent seeing.

I think, therefore, that the dark poles and bright equatorial belt of the first satellite of *Jupiter* thoroughly account for all the phenomena previously reported of the distortion or ellipticity of its disc. This explanation is commended for its simplicity, as it requires no violation of the laws of Nature to satisfy the observation.

It is well here to again make a statement in reference to the discovery of the caps and belt of this satellite. These were discovered by the writer with the 12-inch equatorial of the Lick Observatory, 1890 September 8.

For the facts in connection with this discovery see *A.N.* 2995, p. 318; *A.N.* 3051; *A.N.* 3206, p. 229; *M.N.* vol. li. p. 557, where a drawing is given showing all the phenomena; *M.N.* vol. lii. pp. 14-15; *M.N.* vol. liv. p. 134, where another drawing is given showing the satellite in transit partly occulting its own shadow.

I do not wish it understood that the belt is sharply outlined. It rapidly fades out as it recedes from the equator, but does not terminate abruptly. Or, in other words, the dark polar caps are darkest *at the poles* and become rapidly less intense towards the equator.

I have previously called attention to the fact that this satellite must rotate on an axis almost perpendicular to the plane of its orbit.

I think that the phenomenon of the dark poles of this satellite would rather suggest that its physical condition is not very different from that of *Jupiter*, for the polar regions of *Jupiter* are dark, and so are those of *Saturn*. The density of the satellite is about the same as that of *Jupiter*—another strong proof of actual physical resemblance.

*Mount Hamilton, California:*  
1894 December 27.

*Observations of the Phenomena of Jupiter's Satellites, and of the Transits of the Red Spot, Dark and Bright Spots, &c., at Bermerside Observatory, Halifax, during the Winter of 1894-1895. By Joseph Gledhill.*

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	N. Almanac Time.
1894.				h m s	h m s
Nov. 11	(a) I.	Ec. D.	Fading	10 4 0	10 8 10
			Half gone (?)	10 5 0	
			Just gone	10 8 40	
14	(b) III.	Sh. I.	Internal contact	11 19 30	11 17 0
15	(c) II.	Ec. D.	Fading	9 34 7	9 35 21
			Bisection	9 35 34	
			Just gone	9 37 33	
17	(d) II.	Tr. E.	Internal contact	7 55 0	7 59 0
			Bisection	7 57 0	
			External contact	8 0 0	
Dec. 1	(e) II.	Tr. I.	External contact	9 56 30	9 57 0
			Bisection	9 58 10	
			Internal contact	10 0 0	
	II.	Sh. E.	Internal contact	11 28 0	11 29 0
			Bisection	11 29 30	
19	(f) II.	Tr. E.	Internal contact	6 6 0	6 10 0
			External contact	6 11 0	
	I.	Sh. I.	Internal contact	11 28 0	11 25 0
	I.	Tr. I.	External contact	11 30 0	11 30 0
			Internal contact	11 33 0	
20	(g) III.	Sh. I.	Internal contact	7 12 0	7 11 0
	(h) III.	Tr. I.	External contact	7 22 0	7 26 0
			Bisection	7 26 0	
			Internal contact	7 30 0	
	III.	Tr. E.	Bisection	10 10 0	10 14 0
	I.	Oc. R.	Bisection	10 51 0	10 53 0
			External contact	10 53 0	
	(i) I.	Ec. D.	Fading	8 33 30	8 36 2
			Bisection	8 35 0	
			Just gone	8 36 32	
27	(j) I.	Oc. D.	External contact	10 20 0	10 21 0
			Bisection	10 22 0	
			Just gone	10 23 20	